THE EATING BEHAVIOR OF PIGS AND FEEDER DESIGN

BY

Dr. Harold W. Gonyou
Research Scientist – Ethology
Prairie Swine Centre, Inc.
Saskatoon, Saskatchewan, CANADA

The two variables most often cited when discussing the productivity of growing pigs are average daily gain and feed efficiency. Efficiencies are determined by dividing the product by the input. In the case of feed efficiency, we divide average daily gain by average daily feed intake. The reciprocal of this calculation, the feed:gain ratio is also cited frequently in the industry. Whichever calculation is used, average daily gain and average daily feed intake are the two measures needed to best describe animal productivity and efficiency. These two variables are certainly correlated. In general, the more feed consumed, the greater the gain. But feed intake is dependent upon appetite, and appetite is dependent upon the nutrient needs of the animal. This brings us back to the growth potential of the pig, which determines appetite, which determines feed intake, which determines growth rate. In any given situation of reduced performance, is the problem one of reduced growth potential or of inadequate access to feed?

Pigs achieve their feed intake by eating. This may seem too obvious a statement to consider in this presentation, but it is important to understand if we are to go beyond the rather gross measure of average daily feed intake in our study of pig behavior. Eating behavior is the means by which pigs interact with their environment to obtain their nutrient needs. Eating involves searching for food, regulation of meals, social encounters with penmates, and interaction with the feeder. The eating behavior of pigs can be broken down into various components that allow us to describe changes due to animal development and environmental conditions. Average daily feed intake is a product of the total duration of eating and the rate of eating. In most cases we will express these as minutes per day and grams per minute, respectively. Total duration of eating can also be seen as the product of the number of meals and the average duration of each meal. The number of meals, the average duration of each meal, and the rate of eating can thus describe eating behavior. It is important to reiterate that under ideal conditions, average daily feed intake is a function of growth potential. When conditions are less than ideal, the pig attempts to maintain intake by adapting its eating behavior. Changes in eating behavior will reflect the nature of the environmental stressors affecting the animal.

Meal Frequency

In behavioral terms, a meal is a bout of eating behavior. A bout is best defined as a period of activity that is terminated by a change in motivation. It is not enough that a pig leaves a feeder, but that it does not intend to return, that determines the end of a meal. We see this most clearly if we watch pigs eat from a trough. Pigs may leave the trough only to return to a different location again within a very short period. This brief absence does not represent the end of the

motivation to eat, nor should the return to the trough be considered a new meal. Since it is very difficult to assess the actual motivation of an animal, it is necessary to observe changes in patterns of behavior that are indicative of such a change. In determining bouts of behavior we examine the distribution of intra and inter bout intervals. It is typical that there is a high frequency of very short intervals, and a much lower frequency of longer intervals between periods of the activity. Plotting these frequencies often provides a clear break in the frequency pattern, and this is taken as the point at which a shift is made from intra-bout intervals (brief interruptions within a meal) to inter-bout intervals (longer breaks which indicate a change in motivation) (Martin and Bateson, 1993). The first estimate of the bout criterion interval for eating in pigs was 20 minutes (Hsia and Wood-Gush, 1984). That is, if the break in eating was less than 20 minutes, it was considered the same meal. If the break was greater than 20 minutes, it was considered a new meal when the pig returned to the feeder. More recent data would suggest that the bout criterion interval should be approximately 5-10 minutes (Petrie and Gonyou, 1988; de Haer and Merks, 1992; Ermer et al., 1994).

Several factors affect the frequency of meals in pigs. Growing/finishing pigs housed in groups will eat approximately 7-9 meals per day (de Haer and Merks, 1992; Hyun et al., 1997), but nursery pigs eat more frequently. Petrie and Gonyou (1988) and Ermer et al. (1994) reported meal frequencies of 15-20 per day for recently weaned pigs. Two environmental factors have also been identified as affecting meal frequency. Under continuous light, pigs eat more meals (18) than when provided only 8.5 hr of light (12), at least among individually penned animals (Hsia and Wood-Gush, 1984). However, individually penned pigs have more meals (20) than do pigs in groups of eight (9) (de Haer and Merks, 1992). Although they reported frequency of feeder visits, rather than meals as defined above, Nielsen and Lawrence (1993) demonstrated that as group size on single-space feeders increases, the frequency of feeder visits decreases. Pigs in groups of 5 made 16 visits per day, while in groups of 20, the frequency was only 7. The most dramatic drop in frequency was when group size was increased from 15 to 20 pigs.

Eating Speed

Eating speed is affected by the size of the pig. Hsia and Wood-Gush (1984) concluded that eating speed increased proportionately with body weight. Hyun et al. (1997) monitored eating speed in pigs from approximately 25 to 85 kg. The overall average was approximately 24 g/min, but this increased from approximately 15 to 30 g/min over the weight range studied. The relationship between eating speed and body weight was linear over this weight range.

The form in which a diet is presented will also affect eating speed. Sows take approximately 50% more time to eat the same amount of feed when it is fed as meal, compared to a pelleted from. Addition of water to the meal increased eating speed, but had no effect on the pelleted form. We determined the eating speed of 85-95 kg pigs when fed either meal feed, or meal feed mixed with an equal weight of water (Gonyou and Lou, 1998). The rate of eating (42 g/min) when fed the dry meal appears somewhat faster than that for the pigs in the study of Hyun et al. (1997), but our pigs were in a specific test situation as opposed to commercial conditions as were theirs. The addition of water to the feed increased eating rate to 123 g/min, a factor of nearly 3. In our study on grower/finisher feeders using meal diets, we observed that pigs on wet/dry feeders spent 17% less time eating each day, but actually consumed 5% more feed than did those on dry feeders. The increase in eating speed with wet/dry feeders under commercial conditions was 20% (Gonyou and Lou, 1998).

Group size also affects eating speed as pigs adapt to increased competition for feeder access. When groups of 8 pigs were fed from a single space feeder, they consumed

approximately 32 g/min. However, individually penned pigs ate at a more leisurely 27 g/min (de Haer and Merks, 1992). Nielsen and Lawrence (1993) determined the speed of eating for pigs in groups of 5, 10, 15 and 20, all of which were fed from a single feeding space. The rate of eating on a pelleted diet was approximately 24 g/min for the groups of 5 pigs, and gradually increased to 32 g/min for the groups of 20. This increase in eating speed was necessary to compensate for the reduction in total duration of eating from 63 min/day in the group of 5 to only 48 min/day in groups of 20.

The range of eating speeds reported for growing/finishing pigs ranges from 15 g/min, for small pigs fed a dry meal diet (Hyun et al., 1997), to over 120 g/min during short test conditions with wet feed (Gonyou and Lou, 1998). Under commercial conditions, the maximum speed of eating for large pigs would appear to be approximately 45 g/min for animals eating from wet/dry feeders (Gonyou and Lou, 1998), although Walker (1991) observed eating speeds of over 60 g/min when 30 pigs were fed from a single space feeder. Under some conditions, such as overcrowding, high eating speeds may be indicative of the pigs having to adapt to a stressful situation. However, in other situations, as when water is available in the feeder, a high eating speed may simply reflect a difference in feed form.

Total Duration of Eating

Just as with eating speed, total duration of eating is affected by size of pig, feed type, and group size. Hyun et al., (1997) reported that total duration of eating dropped from over 100 to less than 70 min/day for pigs as they grew from 25 to 85 kg. Similarly, Gonyou and Lou (1998) reported total durations of 102 min/day for pigs weighing approximately 40 kg, and 85 min/day for pigs weighing approximately 70 kg. Because of this reduction in total duration of eating as pigs grow, the number of pigs that can eat from a single feeding space should change with pig size. Although seemingly contrary to common sense, more large pigs should be able to eat from a single space feeder than can small pigs.

Increasing the number of pigs eating from a single space feeder will force the animals to adapt their behavior in order to maintain intake. Larger group sizes will result in a reduction of total duration of eating. Gonyou et al, (1992) did not observe a change in total duration when group size increased from a single pig to five. However, when group size was increased from 5 to 10, 15 and 20, total duration decreased from 63 to 48 min/day (Nielsen and Lawrence, 1993). When 30 pigs were fed from a single space feeder, Walker (1991) reported that the feeder was occupied for 92% of the time. This represents a total duration of eating of approximately 44 min/day.

Diurnal Patterns of Eating

Pigs are generally diurnal or day-active animals. However, the threat of human contact may result in feral pigs becoming nocturnal, particularly during hunting seasons. It would appear that pigs are quite adaptable and can maintain different activity patterns depending upon their circumstances. In commercial conditions, with distinct light and dark periods of the day, pigs exhibit crepuscular activity patterns. There are typically two peaks in eating activity, at the times of lights-on and lights-off (Feddes et al., 1989; de Haer and Merks, 1992). This would correspond to sunrise and sunset in free-ranging conditions. If pigs are illuminated continuously, a single peak in eating extending from morning to afternoon may occur (Gonyou et al., 1992). Continuous illumination results in an increase in the frequency of meals (Hsia and Wood-Gush, 1984), but not in average daily gain (Furlan et al., 1986).

Increasing the number of pigs eating from a single feeding space results in a change in the diurnal pattern of eating. When 5 to 15 pigs are fed from a single space feeder, a distinct crepuscular pattern is evident, with nocturnal occupation rates of less than 40% (Walker, 1991; Nielsen and Lawrence, 1993). When 20 pigs were fed from a single feeding space, daytime occupancy rates were in excess of 80%, with no distinct peaks at lights-on or lights-off. Occupancy rates during the night were moderate, between 40 and 60%. When Walker (1991) increased the group size to 30 pigs, occupancy rates exceeded 80% throughout the 24 hour period.

It might be hypothesized that continuous lighting is a means of increasing the maximum feeder space stocking density. Continuous illumination increases the frequency of meals and more uniformly distributes eating throughout the 24 hour period. During moderately high stocking density (20/feeder space), there is the beginning of a shift from a crepuscular to continuous eating pattern. Such a shift would be facilitated by continuous illumination. However, groups of pigs adapt a nearly continuous eating pattern, even when illumination is not continuous, some time before productivity is affected by group size. It would appear that pigs do not need a continuous lighting pattern in order to increase their level of nocturnal eating.

Social Facilitation

Social facilitation occurs when one animal increases the performance of a behavior due to the presence of another animal performing that same behavior. Synchronized eating has been reported under experimental conditions for growing pigs (Hsia and Wood-Gush, 1984), raising the possibility of using pen and feeder design to increase intake through social facilitation. Gonyou et al. (1992) reported that pigs in adjoining pens, with spindle penning, ate simultaneously more often if the feeders were adjacent to the same pen wall. However, in the same study, pigs within a pen ate individually more than would be expected on a random basis. A subsequent study with larger group sizes confirmed these findings (unpublished data). Hutson (1995) designed feeders such that while pigs were eating they could observe animals in the adjacent pen. Short duration studies suggested that this might increase feed intake. Several feeders have been developed which allow pigs in adjacent pens to see and even touch each other while they are eating, and some manufacturers have claimed this feature resulted in social facilitation. Gonyou (1999) allowed pigs in neighboring pens two types of contact while eating from feeders adjacent to the pen divider. Some pairs of pens were equipped with a spindle pen divider, which allowed visual contact. Other pairs of pens shared a feeder that allowed contact between pens in the feeder trough. The availability of contact while eating increased the synchronization of eating between adjacent pens. However, the total duration of eating was not affected, nor was average daily feed intake increased. It would appear that under growing/finishing conditions, social facilitation is not likely to increase productivity.

Post-weaning Eating Behavior

In free-ranging pigs, the transition from suckling to the consumption of solid food is a gradual process. 'Weaning' may begin within four weeks after birth, but is not completed until the pigs are approximately 17 weeks-of-age (Jensen and Recen, 1989). Under commercial management, pigs are usually abruptly weaned by removing them from the sow's presence. Traditional management in the early part of this century would have been to wean pigs at 8-10 weeks-of-age. More recently, weaning at 4-6 weeks-of-age was common. A post-weaning set-back would occur following weaning as the pigs adjusted to a diet consisting entirely of solid feed. The practice of creep-feeding was advocated as it allowed piglets to become familiar with solid feed before they were weaned. Current practices include early-weaning at 7-16 days-of-age,

or weaning at 3 weeks. In neither situation is creep feeding likely to be beneficial as suckling pigs eat very little solid feed prior to 21 days-of-age (Pajor et al., 1991). Under most current management programs, weaning is abrupt, with pigs having no transitional period that might include both suckling and eating solid feed.

When fed diets based on dried milk products, pigs weaned at 4 weeks-of-age do not show normal levels of eating behavior or feed consumption until the second day after weaning. Pigs weaned at 2 weeks-of-age were delayed an additional 24 hours before eating at normal levels (Metz and Gonyou, 1990). Ermer et al. (1994) demonstrated that newly-weaned pigs preferred diets containing dried porcine plasma to milk based diets, and that intake increased more rapidly when such diets were offered. Using plasma based diets, Gonyou et al. (1998) observed nearly normal levels of eating approximately 24 hours after weaning in pigs weaned at 21 days-of-age. However, pigs weaned at 12 days-of-age did not spend a significant amount of time eating until 36 hours after weaning. A more recent study has confirmed that pigs weaned at 12-14 days-of-age spend less than 2% of the time in contact with their feed during the first 48 hours after weaning. Thereafter, eating increases rapidly to more than 6% of the time. In that same study, we observed that the first contact that pigs had with their food occurred, on average, 150 minutes after weaning. This latency to contact varied from less than 5 to more than 600 minutes. However, all pigs contacted feed well before any significant increase in eating occurred. It would appear that solid feed is not recognized as food by early-weaned pigs for 2-3 days following weaning.

Early-weaning of pigs results in an increase in belly-nosing, which appears to be similar to the massage phase of suckling behavior. Weaning at any age prior to 4 weeks-of-age results in a significant level of this behavior, but the level increases with progressively earlier weaning. Metz and Gonyou (1990) observed that belly-nosing did not appear until the fourth day following weaning, and that it was more frequent in pigs weaned at 2 than at 4 weeks-of-age. Comparing weaning at 12 and 21 days-of-age, Gonyou et al. (1998) reported a similar delay in the development of belly-nosing, and that the peak incidence occurred during the second week post-weaning for both ages of pigs. Worobec et al. (1999) studied weaning as early as 7 days-of-age and observed a similar delay in the development of belly-nosing, even though the levels were much higher in these pigs than those weaned at older ages. Gonyou et al. (1998) continued their observation through the nursery and growing/finishing phases of production. Although the level of belly-nosing and pig-to-pig oral contact decreased approximately 3-4 weeks after weaning, pigs weaned at 12 days-of-age continued to spend more time in these activities than those weaned at 21 days-of-age throughout the study.

The high incidence of belly-nosing has not been shown to be detrimental to the productivity of piglets. Indeed, segregated early weaning generally has a favorable effect on growth rate. There is considerable variation in the amount of belly-nosing performed by piglets within a litter, but again, no relationship to growth rate is evident. Pigs which belly-nose tend to be more active than others in their litter, but do not spend more or less time eating (Gonyou et al., 1998). However, the persistence of belly-nosing and other oral contact with penmates into the growing/finishing period suggests that we need studies on the incidence of tail and flank-biting during the growing/finishing period among early weaned pigs. Producer comments would suggest that these problems have been increased by early-weaning. Recent attempts have been made to re-direct belly-nosing toward other features within the pen (Rau and Duncan, personal communication). Nipples placed in the feed trough attracted rooting behavior, but failed to increase feed intake. However, belly-nosing among the piglets was reduced. Whether this reduction in belly-nosing continues beyond the time that the teat is available is unknown.

Empirical vs. Ergonomic Feeder Studies

Prior to the work of Taylor (1990) and Baxter (1991), most studies on feeder design were empirical in nature. That is, differences in design or management were evaluated solely on their effects on productivity and little information on their effects on eating behavior was collected. The ergonomic approach emphasizes the effects of design features on various aspects of eating behavior, such as total duration, eating speed, head and body position etc. Using an analogy to nutrition research, conventional feeder studies are similar to feedstuff based studies, while ergonomic studies are similar to nutrient based research. In my discussions on feeder design I will rely much more upon ergonomic studies than empirical.

Defining a Feeder Space

Many manufacturers produce feeders with some sort of trough divider, and use the number of such divisions to determine the number of feeder spaces. Unfortunately, this method is frequently misleading, as the resulting spaces cannot all be used simultaneously. Producers, as well as manufacturers, should be aware of how pigs use feeder space and the true number of spaces available in a feeder.

Baxter (1991) studied the behavior of pigs as they ate from a long trough. When no dividers were present, the number of pigs that could-eat from the trough was dependent upon the shoulder width of the pig. Petherick (1983) determined that over the weight range of growing/finishing pigs, the width at a pig's shoulder is approximately 6.1 x $BW^{0.33}$, with width in centimeters and body weight in kilograms. Baxter (1991) recommended an additional 10% to accommodate variation in pig shape and some movement. The resulting width of a true feeding space would be 11.1, 19.8, 24.8, and 32.8 cm, for 5, 25, 50 and 120 kg pigs, respectively.

Although the true feeding space of a pig can be calculated, it will rarely be used to determine the actual capacity of a feeder. If no divisions are used in the feed trough, pigs prefer to space themselves out as much as possible in order to avoid aggression between adjacent animals (Baxter, 1991). Divisions within the trough reduce the frequency of this aggression. Large divisions, which cover the head and shoulder of the pigs, will virtually eliminate aggression between adjacent animals. Such divisions are currently used by several manufacturers. Most single-space feeders also provide such protection to the head and shoulders of pigs while they are eating. Thus, if divisions are fixed, each space must be adequate for the largest pig that will use the feeder. Using the pig sizes mentioned above, a wean-to-finish feeder should not be divided into space less that 32.8 cm as that much space is required for the market animal.

Continuing with this example, let us examine whether a 135 cm feed trough, divided into four (33.7 cm) feeding space could accommodate more than four smaller pigs simultaneously. That is, are there more than four spaces available for younger pigs. Rather than dividing the entire length of the trough by the true feeding width of a pig, we must look at the width of the existing spaces. Two pigs could eat simultaneously from a 33 cm wide space up to a weight of approximately 15 kg. If the shape of the feeder lip would allow pigs to eat side by side, the feeder would provide 8 feeding spaces to pigs up to 15 kg, and only 4 spaces thereafter. There are a few feeders that have adjustable trough dividers. Such feeders could be set to accommodate 8, 7, 6, 5, and finally 4 pigs in this length of trough if management were prepared to make the required changes during the growout period.

Many feeders will have their feed trough divided by simple bars or small panels into widths less than the true feeding space for market pigs. Pigs are still able to eat from these feeders

because their snout or head width is less than the divider spacing, even though their shoulders are wider. However, these pigs could not use all of the feeder holes simultaneously. The number of 'spaces' in many feed troughs does not reflect the number of pigs that can eat simultaneously. The true number of feeding spaces should be determined before calculating the number of pigs to be fed from a feeder.

Accommodating Eating Movements

Taylor (1990) studied the way sows ate from a variety of commercial feeders, and summarized a portion of his results in an article in the National Hog Farmer (Taylor and Curtis, 1988). Up to that point in time, the predominant approach to reducing feed wastage from feeders was to make it difficult for animals to access the feed. By keeping the amount of feed available in the actual feed bowl to a minimum, it was believed that wastage would be reduced. The emphasis at that time was to make the feed bowl small, and to keep feed gap narrow. Taylor's conclusions were that this approach may contribute to feed wastage rather than minimize it. It also increased the amount of time it takes pigs to eat from a feeder and the incidence of eating related injuries to the snout of pigs. Taylor's recommendation was:

"(The) feeder should allow (the) sow to use her individual approach to feed. Because each sow eats in a unique way, give her plenty of space so she can 'do her thing' at feeding time. Among other things, that means providing adequate head room. *This approach runs exactly counter to the very restrictive approach currently found in many feeder designs*." (Taylor and Curtis, 1988).

Baxter (1991) also advocated a similar design approach to grower/finisher feeders. The new emphasis for reducing feed wastage was to control spillage through design of the feeder bowl and lip. Allow the pigs to eat with natural movements, and provide adequate space for the animals to hold their head above the feed bowl while they chew and swallow, and feed wastage should be reduced. The pig's main concern while eating is to eat, not to waste feed. If the design accommodates natural eating behavior without wastage, the pig will not waste a great deal of feed. This new approach to design has had two major effects of feeder management. The first is that less attention need be placed on feeder adjustment. In fact, several feeders no longer allow for operator adjustment. The second is that pigs take less time to access and consume their feed, allowing more pigs to be fed from a single feeding space. The previous rule-of-thumb of no more than 5 pigs per feeder space has now given way to 10 or more pigs per space (Bates et al., 1993; McGlone et al., 1993).

Wet/Dry Feeders

Feeding wet or liquid feed to pigs is not a new concept. Such feeding systems have traditionally been associated with limit-feeding programs in which improved feed efficiency is a major goal. In recent years there has been increased interest in the concept of wet/dry feeding, in which the pig has the option of eating the feed dry, or of mixing it with water before consumption. Various methods are used to provide access to feed and water in these feeders. Some feeders provide an elevated shelf from which dry feed is obtained. The feed can be consumed directly from the shelf, or nosed off the shelf into a feeding pan below, which may be flooded with water from a nipple. Other feeders allow pigs to access dry feed by means of a lever that drops the feed into the feed bowl. A water nipple or button drinker is located within the feeder and may be used to drink water directly, or allow it to mix with the feed. A key feature of wet/dry feeders is the separation of feed and water source. If water is allowed to contact the access point of the feed, the water will 'wick' into the feed storage and plug the feeder.

Despite the fact that eating from a wet/dry feeder involves accessing both feed and water separately, pigs eat faster from wet/dry feeders. In our study of six different models of wet/dry feeders, which included five substantially different ways of accessing feed and water, eating speed was increased by 20% over the dry feeders studied (Gonyou and Lou, 1998). Pigs eating from wet/dry feeders also entered the feeder fewer times each day than did those fed from dry feeders. In general, pigs fed from wet/dry feeders ate quickly and were able to remain for longer periods in the feeders. This latter finding may be due to the fact that pigs did not have to leave the feeder if they wanted to drink during the meal.

There have been several empirical studies in which one model of wet/dry feeder was compared to one model of dry feeder. In general, the pigs on the wet/dry feeder grew as well as or faster than those on dry feed (Anderson et al., 1990; Walker, 1990). In one of the first studies to examine a number of models of commercial wet/dry feeders, as well as commercially available dry feeders, Payne (1991) concluded that the wet/dry feature resulted in increased growth but no increase in apparent feed intake. However, he suggested that the level of feed wastage may have been less in wet/dry feeders and that actual feed consumption was higher. We included six commercially available models of wet/dry feeders in our study, comparing them with six models of dry feeders. The wet/dry feature was responsible for an increase in feed intake of 5%, as well as a similar increase in average daily gain. Our study included both single and multiple space feeders. It is possible that the pigs on single-space dry feeders were more crowded on the feeder than were the pigs on wet/dry feeders. At a feeder stocking density of 12 pigs/feeder, pigs on single-space dry feeders had a feeder occupancy rate of 80%. However, the pigs on single-space wet/dry feeders consumed more feed and grew more quickly that did pigs on multiple-space dry feeders (12 pigs/feeder), which would have had a lower feeder space stocking density. Wet/dry feeding will increase intake and growth rate by approximately 5% in growing/finishing pigs.

The advantage of wet/dry feeders may not be present with nursery pigs. Reese et al., (1990) did not find a difference in performance in nursery pigs fed from wet/dry or dry feeders. In our own study, we did not see a difference in either intake or growth during the first 4 weeks of the growing/finishing period. It is not clear if this lack of difference is truly age dependent, or the result of a period of adaptation to wet/dry feeding. At any rate, the improvement in intake and growth seen on wet/dry feeders in near-market animals will exceed the average of the entire growing/finishing period.

Feed Wastage and Feeder Design

We examined the level of feed wastage in 12 commercial feeders in our study (Gonyou and Lou, 1988). We divided wastage into different components: spillage, leavage and adherence. Spillage was defined as feed collected from under the floor in the area of the feeder. Leavage was defined as the feed remaining in a feeder after the pigs have removed as much as they could access. Adherence was the feed left on the pig's snout and face when it left the feeder. Leavage was not affected by the availability of water in the feeder, but was affected by the design of the feeder bowl. Angular corners resulted in greater leavage than did rounded corners. Larger pigs had more difficulty accessing feed in the corners of feeders and leavage levels for large pigs (80 kg) were approximately four times as great as for small ones (45 kg), being 77 and 18 g, respectively.

We determined adherence by catching pigs and cleaning their snouts and faces both before and after a staged eating bout. Pigs leaving the feeder had an average of 1.5 g of feed adhering to their snout and face. This may seem insignificant, except that pigs entered and left the feeder

approximately 60 times per day in our studies. This could amount to wastage of 90 g/pig if all feed fell off before the subsequent eating bout. However, I believe this would be an overestimate as much of this feed would remain on the pig until the next meal.

We determined n average spillage level of 3.4% of feed disappearance in our study. Individual models of feeders range from 2.0 to 5.8%. There were no differences between dry and wet/dry feeders, nor between single and multiple space models. We did find a significantly higher percentage wastage by small pigs (45 kg, 4.4%) than by large pigs (80 kg, 2.4%). The feed used for smaller pigs is generally more expensive than that fed large pigs, and so the problem of wastage is particularly important for the grower stage.

We videotaped the pigs while they ate in order to determine what behaviors were associated with feed falling onto the floor. Feed was observed to drop from the mouth of the pig while it held its head up to chew and swallow more often in large pigs that in small. This finding supports a suggestion of Taylor (1988) that pigs should be able to stand with their head inside the feeder while chewing. The larger pigs in our study were less able to do this due to the relative depth (lip to feed access) of the feeder compared to smaller pigs. However, this would not explain the greater wastage by smaller pigs.

Spillage was more often associated with fighting and stepping into the feeder in small pigs than in large. The feeding space in one of the feeders in our study was several cm wider than necessary for our market weight. We often observed more than one small pig eating from a single feeding space at the same time, and this usually involved some fighting. It was this type of situation that contributed to the large wastage in small pigs. In wet/dry feeders, two small pigs eating at the same time would also 'drop' feed on each other's head, which also contributed to spillage. These observations reinforce the importance of sizing the feeder space appropriately so that it is only wide enough to accommodate the market-sized animal.

We had assumed that the height of the feeder lip would affect the frequency of pigs stepping into the feeder. This was not the case. Small pigs would go over a very high lip if it was necessary to reach the feed. The more important factor was the depth of the feeder, from the feeder lip to the point of feed access. For small pigs (22 kg), the incidence of stepping into the feeder exceeded 50% of all eating bouts if the depth was 20 cm. For large pigs (96 kg), no animals stepped into the feeder when the depth was 20 cm. The 50% stepping in level was only reached somewhere between 30 and 40 cm of depth. This data would suggest that we could reduce spillage by designing feeders that are less than 20 cm in depth. However, large pigs cannot easily eat from such a shallow feeder, doing so only by twisting the head and forcing their snout down near the feeder lip. For growing/finishing pigs, a compromise in feeder depth is necessary. A depth of more than 20 cm is necessary for the larger pigs, but this will result in greater feed wastage by the smaller pigs. The problem is compounded even more if wean-to-finish systems are employed.

Feeder Space Stocking Density

As indicated earlier, the current approach to feeder design allows pigs to eat more naturally and has lowered the total duration of eating. The traditional recommended feeder space stocking density of 5 pigs/feeding space does not apply to most feeders. Bates et al. (1993) and McGlone et al. (1993) have indicated that pigs may be stocked at a rate of 10 pigs/feeding space. In our study we used 12 pigs/pen for both single and multiple space feeders. Within both dry and wet/dry feeders, pigs on single-space feeders performed as well as those on multiple space models. Walker (1991) and Nielsen and Lawrence (1993) observed no difference in productivity

of pigs between feeder space stocking densities of 10 and 20 pigs/feeding space. In fact, Walker (1991) did not find a difference in productivity between 10 and 30 pigs/feeding space during the finishing period, although there was a difference when pigs were younger. How many pigs can be fed from a feeding space?

The upper limit of feeder space stocking density is likely to be related to some level of feeder space occupancy. In our study, 12 pigs on a single space feeder would occupy the feeding space between 65 and 85% of the time, depending on size of the pigs and whether or not water was available in the feeder. Walker (1991) saw no effect on productivity when feeder space occupancy rates were between 80 and 90%. When occupancy rates exceeded 90%, as with small pigs stocked at 30 pigs/feeding space, he saw a reduction in feed intake and growth. It appears that feeder occupancy levels of 80% will support maximal intake and growth. With the information currently available, I am hesitant to increase that level to 90%.

The number of pigs present and their total duration of eating determine occupancy rate. Walker (1991) and Nielsen and Lawrence (1993) reported a total duration of eating of less than 50 min/day for their larger group sizes. Hyun et al. (1997) reported a total duration of approximately 70 min/day for large pigs, while we observed values of less than 75 min/day for two of the models of feeders we studied. If the total duration of eating averaged 50, 60, 70 or 80 min/day, then the maximum feeder space stocking density that would keep occupancy rates below 80% would be23, 19, 16, and 14, respectively. Two factors known to affect total duration of eating are pig size and the availability of water within the feeder. Higher feeder space stocking densities can be achieved if pigs are fed from wet/dry feeders, and if only finishing pigs are fed from the feeder. However, in the typical grower/finisher situation, the feeder space stocking density should be established for the smallest pigs on the feeder, that is, during the early grower period.

Based on the results of our study with 12 commercial feeders, and using a maximum feeding space occupancy rate of 80%, the range of recommended feeder space densities would vary from 9 to 16. However, that study used a constant group size of 12 pigs/pen. The studies of Walker (1991) and Nielsen and Lawrence (1993) indicate that as feeder space density increases, pigs adapt their eating behavior to reduce total duration of eating. To determine the maximum feeding space density for a particular feeder it is necessary for us to obtain three critical pieces of information. The first is the occupancy rate at which productivity is affected. Our current estimate of between 80 and 90% is not accurate enough. The second is the total duration of eating for the pigs and feed to be used in the production system. It may be possible to obtain this from a standard feeding behavior study with a set number of pigs under the proposed feeding program. The third is to determine the extent to which those pigs will adapt their eating behavior as feeding space stocking density increases. This will require a series of titration studies.

Concluding Comments

Feeder design has change dramatically in the past 20 years. Feed wastage of less than 3% for finisher pigs and less than 5% for grower pigs is commonly achieved without undo emphasis on feeder adjustment. This change has come about with a shift in emphasis from restricting eating behavior, to accommodating natural eating movements within the feeder. Associated with this same approach is a reduction in total eating duration, which has increased the maximum feeder space stocking densities among commercial feeders. Making water available in the feeder has also reduced total duration of eating, and has resulted in an increase in feed intake and average daily gain. Understanding some of the relationships among eating speed, wet/dry feeding, pig size, feed wastage, average daily gain and other important variables has come about

through an increased use of behavior studies in growing/finishing pigs. However, it is also clear that eating behavior is complex and that new development in swine management will likely affect how pigs eat. We can expect new development in the areas of early-weaned pigs, group size and pen design that will require further research into eating behavior.

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